Managing Africa's Soils No. 8

# Participatory research on compost and liquid manure in Kenya

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## About the authors

Davis D. Onduru works for the Kenya Institute of Organic Farming in Nairobi, Kenya and is an agronomist. G.N. Gachini is a soil-scientist based at the National Agricultural Research Laboratories at the Kenyan Agricultural Research Institute (KARI) in Nairobi. André de Jager is an agro-economist and works at Agricultural Economics Research Institute (LEI-DLO) in the Netherlands. Jean-Marie Diop is an agronomist working for Education Training Consultants (ETC), The Netherlands. The corresponding author, Davis Onduru, can be contacted at P.O. Box 34972, Nairobi; Fax 254-2-583570; Tel: 254-2-583383/583194; E-mail: kiof@iconnect.co.ke

## About NUTNET

NUTNET stands for *Networking on soil fertility management: improving soil fertility in Africa-Nutrient networks & stakeholder perceptions*. NUTNET is a partnership of 15 organisations coming from 6 African and 2 European countries. They are INERA, Burkina Faso; SOS Sahel, Ethiopia; KARI, KIOF & ETC East Africa, Kenya; IER, Mali; Environment Alert & Makerere University, Uganda; IES, Zimbabwe; IIED & IDS, United Kingdom; AB/DLO, LEI/DLO, SC/DLO, ETC & KIT, The Netherlands. It was drawn up with the primary aim of bringing together the following three research programmes:

- *The dynamics of soil fertility management in savannah Africa* co-ordinated by IIED and IDS/UK;
- *Spatial and temporal variation of soil nutrient stocks and management in sub-Saharan Africa systems* (VARINUTS) co-ordinated by SC/DLO, the Netherlands;
- *Potentials of low-external input and sustainable agriculture to attain productive and sustainable land use in Kenya and Uganda* (LEINUTS) co-ordinated by LEI/DLO, the Netherlands.

NUTNET has been made possible through generous funding from the Netherlands Development Agency (NEDA), Ministry of Foreign Affairs, the Netherlands

## Acknowledgements

This paper is based on results of the LEINUTS programme which is funded by the research programme of the European Community (INCO-DGXII).

Design and production by Eileen Higgins and Bridget Tisdall
Cover illustration © Christine Bass, based on Bogolan fabric patterns
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# Summary

Soil fertility is declining in Kenya's low potential areas. More appropriate soil fertility management technologies are needed, which fit into farmers' socio-economic circumstances. This working paper presents the methodology and results of an on-farm experiment with the use of compost and liquid manure on maize, using a Participatory Technology Development (PTD) approach. It was done with two groups of farmers. One group was composed of conventional farmers while the second group comprised farmers using a Low External Input and Sustainable Agriculture (LEISA) approach. The PTD work started with debate amongst farmers and researchers on soil fertility management, followed by identification of promising technologies. This study has shown that with a PTD approach, farmers and researchers can come to agreement on technologies to be tested, treatments and research design.

Compost and liquid manure were the technologies jointly selected by both groups of farmers and researchers for participatory on-farm research. The first treatment is what farmers normally apply which is on average 16 t/ha compost in the case of LEISA farms and a combined application of 16 t/ha "Boma" Manure and 57 kg/ha DAP in conventional farms. The second treatment involves a doubling of LEISA farmers' current compost application rate while the third treatment is a combined application of $T_2$ with 7 t/ha of liquid manure. Farmers and researchers wanted to compare the impacts of these technologies on maize with respect to soil nutrient balances and the agro-economic performance.

The analysis of data collected by researchers on the performance of the various treatments, correlates well with farmers' evaluation. Both LEISA and conventional farmers consider that the treatment which combines compost with liquid manure produces the best results. Positive features identified by farmers are an improvement of soil structure, soil fertility, crop growth and vigour, leaf colour intensity, and maize yields. It also saves on cash inputs as it replaces fertilisers in the case of conventional farmers. Yet, the new technologies are considered to demand a lot of labour and require substantial amounts of organic material for producing compost. The calculation of a partial nutrient budget showed that current management practices for maize cultivation in Machakos for both LEISA and conventional farmers result in net negative nitrogen balances. This is still the case even when the compost application rate is doubled, though the phosphorus balance becomes positive. Only the combined use of compost and liquid manure has a positive impact on both nitrogen and phosphorus balances. A further insight into the performance of these technologies is expected through analysis of residual effects of the treatments in the second year of the trials.

# Recherche participative sur le compost et le lisier au Kenya


## Résumé

La fertilité des sols décline dans les régions kenyanes à faible potentiel agricole. Des technologies plus appropriées sont nécessaires pour gérer la fertilité des sols tout en tenant compte des circonstances socio-économiques des paysans. Le présent document de travail présente la méthodologie et les résultats d'un essai effectué portant sur l'utilisation du compost et du lisier (engrais liquide) dans la production de maïs, à partir d'une approche de Développement Technologique Participatif (DTP). Elle portait sur deux groupes de paysans. L'un d'eux était composé de paysans conventionnels tandis que l'autre comprenait des paysans ayant adopté une approche basée sur l'Agriculture Durable à Faibles Apports Extérieurs (*LEISA* en anglais). Le travail de DTP commençait avec un débat entre paysans et chercheurs sur la gestion de la fertilité des sols, suivi d'une identification des technologies les plus prometteuses. Cette étude aura montré qu'avec l'approche DTP, les paysans et les chercheurs peuvent se mettre d'accord sur les technologies à tester et les traitements de l'essai.

Les paysans et les chercheurs ont sélectionné conjointement le compost et le lisier comme les technologies à retenir pour effectuer des recherches participatives dans les exploitations. Le premier traitement représente ce que les fermiers appliquent généralement, à savoir 16 t/ha de compost en moyenne dans le cas d'exploitations LEISA et une application associant 16t/ha d'engrais "Boma" et 57 kg/ha de DAP dans les exploitations conventionnelles. Le deuxième traitement consiste à doubler l'application de compost des paysans LEISA, tandis que le troisième est une application associant le deuxième traitement et 7t/ha de lisier. Les paysans et les chercheurs voulaient comparer les impacts de ces technologies sur le maïs au niveau du bilan des éléments nutritifs dans le sol et de la performance agro-économique.

L'analyse des données recueillies par les chercheurs concernant la performance des divers traitements est en corrélation avec l'évaluation des paysans. Les agriculteurs tant LEISA que conventionnels considèrent que le traitement associant compost et lisier donne les meilleurs résultats. Les éléments positifs notés par les paysans sont une amélioration de la structure et de la fertilité du sol, croissance et vigueur de la récolte, intensité de la couleur des feuilles et de la production de maïs. Cela permet également de faire des économies dans la mesure où il n'y a pas à acheter d'engrais comme dans le cas des paysans conventionnels. Pourtant, ces nouvelles technologies sont considérées comme exigeant beaucoup de travail et consommant de grandes quantités de produits organiques pour faire du compost. Le calcul d'un bilan partiel des éléments nutritifs a montré que les pratiques actuelles de gestion de la culture du maïs à Machakos, chez les paysans – tant LEISA que conventionnels – aboutissent à un déficit net en azote et que c'est toujours le cas lorsque l'application de compost est doublée, bien que là le bilan en phosphore devienne positif. Seule une utilisation associant du compost et du lisier a un impact positif sur les teneurs à la fois en azote et en phosphore. On devrait en savoir plus sur l'efficacité de ces nouvelles technologies avec l'analyse des effets résiduels de ces traitements qui sera faite durant les essais de la seconde année.

# 1 Introduction

In Kenya, farming is carried out under highly diverse agro-ecological conditions, soil fertility levels and socio-economic circumstances. Population density is rising and one result is a migration towards relatively low potential, marginal areas such as the Machakos district, where soil fertility is relatively poor and requires careful management (Tiffen *et al.*, 1994). Studies conducted in semi-arid areas of the Machakos District indicate decreasing per capita production which is attributed to declining soil fertility (McCown, *et al.*, 1990). Another study carried out in this area shows that the current farm management system results in nitrogen depletion at the rate of 53 to 56 kg/ha/yr implying that 60-80% of farm income is based on nutrient mining. Phosphorus is depleted at the rate of 9 to 13 kg/ha/yr (De Jager *et al.* 1999).

Improving soil fertility management requires that appropriate technologies are made available to farmers that fit their socio-economic circumstances. Moreover, the decision to adopt a new technology is more than just purely a technical option. It is a holistic and complex trade-off among various household needs and objectives. Using approaches that allow for farmers' participation in research and technology development is of paramount importance to assure their adoption and diffusion (Altieri *et al.*, 1997; Defoer *et al.*, 1998, Ashby, 1991). Until recently the importance of farmer participation in the development of soil fertility management technologies has been under-estimated by soil scientists. Yet, there is now abundant evidence that farmers all over the world are experimenters. Their experience and skills are now regarded as important in the development of appropriate interventions in soil fertility management (Brokensha *et al.* 1980, Vlaming *et al.* 1997).

Participatory Technology Development (PTD) is one approach that can facilitate the quest for appropriate, integrated soil management technologies. PTD is a process for generating new technologies which involves all stakeholders (farmers, researchers and other users) in priority setting, designing, testing out the new practices, and sharing the results. It also involves the creation of favourable conditions for continuous experimentation and sustainable agricultural development. PTD can play a crucial role in facilitating effective communication among the various stakeholders and assure that farmers' opinions, reactions and evaluation criteria are incorporated in the assessment of new technologies (Reijntjes *et al.*, 1992; Diop *et al.*, 1997; Deugd *et al.*, 1998).

In the last decade, PTD and other participatory tools (e.g. Participatory Rural Appraisal) are increasingly used in Kenya to diagnose farmers' problems and plan research activities. KIOF started using the PTD approach in 1993. It is relatively new in KARI but gaining importance. This working paper describes the use of a PTD approach in initiating a debate with farmers on soil fertility management followed by an identification of technologies for on-farm testing. Emphasis was on Low External Input and Sustainable Agriculture (LEISA) technologies, because farmers' economic constraints limit their possibility to purchase inputs.

The main objectives of the study were to:
- Identify LEISA technologies with a potential to address soil fertility constraints in the present farming system.
- Assess potentials, limitations and sustainability of selected LEISA soil fertility management technologies through participatory on-farm research.
- Initiate and enhance learning by farmers, extension staff and researchers and adoption of soil fertility management technologies through participatory on-farm research.

Compost and liquid manure were the soil amendments jointly selected by farmers and researchers for participatory on-farm research and evaluation. Composting in low potential areas is often not regarded as a viable option due to the limited quantity and quality of biomass available for composting (Kariuki *et al.*, 1994; Hamilton, 1997). However, farmers were of the opinion that evaluating the potential of composting and liquid manure for low potential areas of Machakos was important, as these technologies can provide solutions to declining soil nutrient status, low levels of soil organic matter, low soil moisture holding capacity and the limited possibility of using external inputs (see also Dalzell *et al.* 1979). The potential for improving the quality of compost and of liquid manure is now being explored by KIOF and KARI in the Kalama division, as one of the possible options for improving soil fertility management. While compost had been used in the past, liquid manure is a relatively new technology in Kenya.

# 2 Choice of site and methods

## Study site

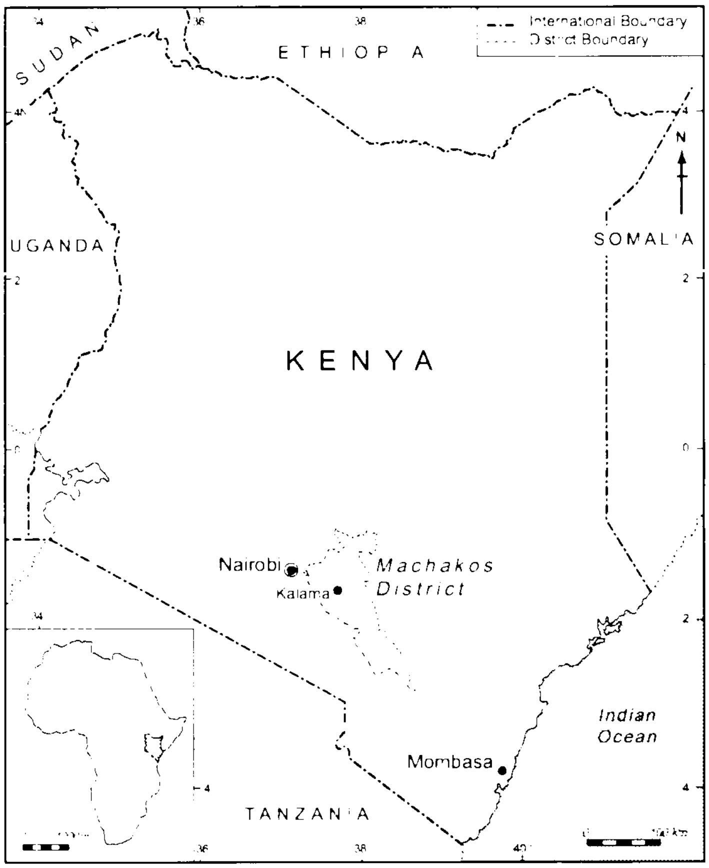
The research was conducted in Muumando Location, Kalama Division, situated in Machakos District of Kenya (Figure 1). Machakos District is located in the Eastern Province of Kenya and considered as a Low Potential Area (LPA). The population of the District is about 1,050,000 persons. It covers an area of 616,300 hectares of which 85% is classified as arid or semi-arid. In the centre of Machakos District, hills rise to 1800-2100 metres and are surrounded by an extensive plateau sloping from 1700 metres in the west down to 700 metres in the south-east. Rainfall received in the District has a bi-modal pattern and the average varies from 500-1500 mm depending on location and altitude. The research site has two growing seasons per year with a total length of 90-119 days. The soils[1] are shallow and well drained, with top soils of loamy sand to sandy loam in many places. They are deficient in nitrogen, phosphorus and organic matter. (Jaetzold and Schmidt, 1982; Kassam *et al.*, 1991). Problems faced in the District include declining soil fertility, decreasing per capita arable land, unpredictable and unreliable rainfall and limited use of agricultural inputs (DAO 1996).

In the last six decades, the farming systems have changed from being extensive and livestock-oriented to intensive and crop-oriented systems. The cropping enterprise has similarly evolved from a system dominated by traditional staple foods, notably sorghum and millet to one that is concentrating on maize and pulses. Crops grown include maize, pigeon peas, sorghum, beans and fruit trees. Local breeds of cattle are kept and grazed on common pastures while farmland is held under a free-hold tenure system. Farming is now mainly subsistence oriented.

Soil and water conservation (SWC) measures coupled with water harvesting techniques are extensively practised in the District to conserve the fragile soils (Tiffen *et al.*, 1994). These include terraces (mainly bench terraces in the steep slopes), cut off drains, stone lines, trash lines, addition of farm-yard manure, crop residue management including mulching, and use of cover crops.

[1] Ferralo-haplic Acrisols with Luvisols and Ferralsols

Figure 1: Machakos District, Kenya




Composting and the use of "boma" manure were already practised in the study site many years before independence to replenish soil fertility when shifting cultivation was increasingly abandoned. Both technologies were promoted between 1930 and 1944 by the Ministry of Agriculture. The adoption was rapid in the case of boma manure but slow for pit composting. After independence (1963), manure use decreased, initially due to active promotion of inorganic fertilisers by Government agencies. However, at present, in spite of active promotion of mineral fertilisers, most food crops are grown using boma manure or compost, sometimes in combination with some mineral fertilisers. Use of fertilisers on horticultural and irrigated crops is much higher. Virtually all farmers use boma manure, which is collected from the "overnight-kraal" and used to fertilise portions of the farm on a rotational basis. The quantity produced is inadequate for fertilising all fields in a single cropping season.

The early promotion of pit composting was not sustained. It was gradually abandoned in the 1940s, because boma manure was a cheaper and easier alternative. Composting was re-introduction in the 1960s by NGOs and the Ministry of Education which made it compulsory for all elementary schools. Emphasis was on pit composting. Attention to this technology further increased during the 1980s following the advent of 'sustainable agriculture' in Kenya as promoted by several NGOs. They promoted composting to increase the use of organic material, reduce the burning effect of not well-composted boma manure and diminish the incidence of pests and diseases. Currently, composting is also becoming more popular due to a decline in the livestock population which affects the availability of boma manure.

# Farm selection and farm characteristics

The on-farm trial was implemented by 10 farmers classified as conventional farmers and 8 LEISA farmers in 1998. The households were selected after an initial workshop with the community attended by conventional farmers, LEISA farmers, extension staff and government administrators. Criteria used for farm selection included willingness to participate in the exercise, household size, location, area of land cultivated, main crops grown, slope, type and number of livestock, market orientation, mechanisation and contacts with extension/research. The selection criteria used are based on an earlier study of the farming systems in the research site. LEISA farms were classified as those practising composting, liquid manure, plant tea[1], double digging, deep digging and natural pesticides while conventional farms did not use any of these technologies. The selected farmers were representative for low potential, semi-arid areas of Kenya.

Table 1. Characteristics of conventional and LEISA farm households

| | Conventional | LEISA |
|---|---|---|
| No. of farmers | 10 | 8 |
| Female headed households (%) | 30 | 0 |
| No. of households where women participated in the trials (%) | 80 | 50 |
| Average household size | 6.6 | 5.1 |
| Labour capacity (family) | 2.4 | 2.6 |
| Average land size (Ha) | 2.5 | 2.5 |
| Average No. of cattle | 2.5 | 5.1 |
| Average Tropical Livestock Units (TLU) | 3.3 | 3.7 |
| Total capital (US$): Land, livestock, equipment | 2,973 | 2,614 |

Adapted from De Jager et al. [illegible]

[1] Plant tea is a top dressing product prepared from succulent plants fermented in water

Characteristics of the farms studied are shown in Table 1. Farming in both conventional and LEISA systems is subsistence oriented, maize and beans being grown as the main crops on steep fields. The average slope varies between 15 and 25%. All heads of the farming households had a least a primary or elementary education. Half of the farmers had completed secondary education while 13% of the LEISA farmers have ever finished post-secondary education. Both groups have had contacts with extension personnel. Labour is provided largely by family members. Many women participated actively in the implementation of the trails and the various meetings (see Table 1).

# Approach

The approach followed five steps:

1 Training of research staff in PTD and farmers' learning concepts;
2 Analysis of farmers' current soil fertility management practices and problem definition;
3 Data collection on LEISA techniques and their impacts in the research sites;
4 Workshop to design the experiment;
5 Evaluation of the trials

Research staff were trained in PTD approach to enhance their skills in verbal and visual tools important for participatory on-farm experimentation (Conway, 1987; Steiner, 1987; Werner, 1993). Assessment of the farming system and soil fertility management practices was done using Participatory Rural Appraisal (PRA) tools, particularly soil mapping and transect walks, to enhance farmers' articulation of soil fertility management issues (Chambers, 1991; SDC, 1993; Onduru *et al.* 1998). The results confirmed those of other studies carried out in Machakos which concluded that soil fertility is a constraint to crop production. Preliminary data collection on LEISA technologies and farmers' evaluation criteria was carried out in the research site.

The results were used in a joint farmer-researcher discussion workshop. Its aim was to select LEISA soil fertility management technologies for on-farm experimentation and develop a trail design. Methods used to stimulate discussions and facilitate decision-making included 'ice-breakers', sub-group discussions, plenary presentations, visual tools and brain storming. Seventeen farmers and four research and NGO staff participated in this workshop. The participants first drew up an inventory of researchers' and farmers' expectations as well as a list of possible areas for research (see Tables 2 and 3).

The next step was to match farmers' and researchers' expectations and to select one LEISA technology for experimentation through discussion in plenary (see Figure 2). The selected technology was then explored and discussed. After an introduction to systematic experimentation, farmers and researchers started negotiations on the design for the on-farm experiment and data collection.

Table 2. Expectations of Researchers and NGO staff and proposed areas of research

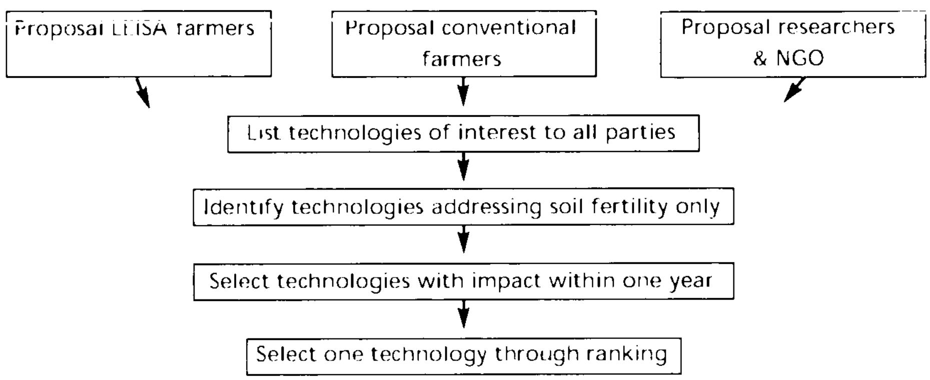
| **Expectations** | **Proposed areas of research** |
| --- | --- |
| • Assess the impacts of jointly selected LEISA technologies, with a high potential to improve soil fertility, through on-farm research<br>• Develop an action-plan for on-farm research<br>• Enhance farmers' knowledge and skills relating to systematic on-farm experimentation<br>• Sensitise conventional farmers on principles and practices of LEISA techniques | • Improve quality of Boma compost through use of additives such as egg shells, wood ash and *Tithornia*<br>• Assess potentials of compost, liquid manure, plant tea<br>• Test use of rock phosphates<br>• Combine rock phosphate and compost |

Tabel 3. Farmers' expectations and proposed areas for research

| **LEISA farmers** | **Conventional farmers** |
| --- | --- |
| To learn about and experiment with:<br>• Easy ways of making double dug beds<br>• Effective LEISA methods of pest management particularly for weevils<br>• Recommended compost and liquid manure application rates<br>• Crop rotation techniques<br>• Soil conservation techniques that are easy to implement<br>• New methods of making compost<br>• How to balance plant nutrients in composts<br>• Soil fertility management techniques<br>• Recommended land tillage practices<br>• Napier grass management<br>• Livestock management<br>• Combining fertilisers and manure while planting<br>• LEISA techniques of planting crops<br>• How to stop chickens from eating eggs | To learn about and experiment with:<br>• Fertiliser application rate when planting<br>• Use of fertilisers in combination with manure or compost<br>• Whether the same fertiliser used in planting maize can be used to plant beans<br>• How to use liquid manure when planting food crops<br>• What causes the increased incidence of maize smut attack when manure is used, particularly when applied as top dressing<br>• Pesticides used in controlling cut worms and maize stalk borer<br>• How to improve the status of phosphorus in the soil<br>• How best to practise mixed cropping<br>• Added advantages, if any, of LEISA farming over conventional farming practices |

The discussion about experimentation started with an inventory of farmer experience with soil fertility related experiments. The intention was that this would help them to formulate proposals for systematic experimentation with soil fertility management. The choice of test crop and the design of treatments was made through a participatory process. The three groups first discussed their proposals in sub-groups which were then presented in plenary for discussion (see Annex 1). The differences and similarities in the options presented became the basis to arrive at a common course of action.

Figure 2: Steps taken to match farmers' and researchers' proposals




Farmers' views were diverse with respect to the technologies to be tested, regarding crops, plot sizes, input types and rates of application. The criteria used for finding a compromise was the feasibility for on-farm research and suitability for all farmers. Methods used were ranking and discussion. The group finally opted for a test with maize using an indigenous variety. The research hypothesis was formulated jointly as follows: *"If we apply compost and liquid manure in planting maize, yields will increase because compost and liquid manure improve soil nutrients status and water holding capacity provided there is enough rainfall"*.

The treatments, plots size, spacing of maize, type of tillage and way of compost application methods agreed upon are presented in Table 4. The rationale for proposing 7 tons/ha of liquid manure was based on a previous survey of LEISA farmers' practices. Liquid manure is a top dressing product prepared from fermented fresh animal droppings in water. It is applied to the soil near the plant roots when crops are knee-high to stimulate fast growth of the crop. The use of 1 kg-tin full of compost (32 t/ha) was based on farmers' desire to find out what happens when the current rates of compost application are doubled. It was also decided to evaluate the residual effects of these doses in subsequent seasons.

Farmer and researcher criteria for monitoring and evaluation of the trials were inventoried during the workshop (see Table 5). These include leaf colour, crop yields, rate

Table 4. Farm experiments: treatments agreed upon

| Treatment | Conventional | LEISA farms |
|---|---|---|
| All | Plot size 9 x 5 $m^2$; Shallow tillage Spacing of maize: 0.3 m x 0.45 m | Plot size 9 x 5 $m^2$; Shallow tillage Spacing of maize: 0.3 m x 0.45 m |
| $T_1$ Control | 1/2 Kg- tinful of cattle manure/ planting hole (16 t/ha) + inorganic fertilisers at normal rate, 1 pinch of fertiliser/ hole (57 kg/ha) | 1/2 Kg-tinful of compost per planting hole (16 t/ha) |
| $T_2$ | 1 Kg-tinful of compost per planting hole (32 t/ha); | |
| $T_3$ | 1 Kg-tinful of compost / planting hole (32 t/ha) + Liquid manure (1 cupful/ planting hole, 7 t/ha) | |

of crop growth and vigour, weight of stover, size of leaves, stem and cobs, pest and disease incidence, height of crop, weed population, fast germination of seeds, effect on soil characteristics, labour requirements, quantities of inputs other than labour and savings on cash inputs. The workshop ended with the identification of follow-up activities.

Table 5. Inventory of farmer and researcher criteria for evaluating trials

| Farmers' criteria | Researchers' criteria |
|---|---|
| • Soil structure and perceived fertility | • Soil nutrient levels and nutrient balances |
| • Labour input | • Quality and quantities of inputs |
| • Crop vigour | • Quality and quantities of outputs |
| • Crop yields | • Crop development data |
| • Savings on cash costs | • Economic performance |
| • Cash income | |
| • Incidence of pests and diseases | |

# Implementation, data collection and evaluation

After the workshop, individual farm visits were carried out to discuss further with farmers about trial sites and to jointly layout the experiment. The plot size became rather small because the test was started late in the season when farmers had already planted most of their fields. All farmers used the pit composting technology. The first pit is filled with layers of manure, dry coarse materials (crop residues), wood ash, top soil and finally green materials (weeds, *teutonia*). After three weeks the content is turned into a second pit and again after three weeks into a third pit. The compost is ready for use after another 2 weeks. Periodic watering is necessary. Farmers used their own material. Sometimes they also cut prunings and grasses along the roadsides.

Data were collected monthly for all the selected indicators, using simple record sheets. One set of sheets was made for farmers on which they themselves recorded certain data (see Annex 2 for an example). The other set of sheets was filled in by researchers. Initially, farmers found it difficult to record the various data on their trial sheets. However, after some time, they became used to the exercise. They even started to take additional notes of their own farm operations. Data collected by farmers and researchers were then processed, and analysed, followed by a joint discussion on results.

A participatory evaluation of the trials was conducted to draw out farmers' opinions, preferences, criticisms and suggestions about the technologies tested and their acceptability for dissemination. A first evaluation was conducted during a field day when crops were still in the ground. The second evaluation took place at the end of the trial, first with each farmer and then in a group.

The individual farmer's evaluation centred on a comparison between their usual practice and the tested technologies, through matrix ranking based on farmers' criteria. The group evaluation consisted of discussions involving farmers, extension staff and researchers. This meeting covered the sharing of trial results, an inventory of constraints faced by farmers during the trials, suggestions for improvement and an action plan for the next trial. The results presented were aggregations at group level for certain selected parameters. In addition, individual farmers were each given their own results in the form of farmer feedback sheets.

# 3 Results

The results of the tested technologies on the agro-economic performance of maize cultivation and on soil nutrient balances are presented in Table 6.

Table 6. Agro-economic performance and soil nutrient balances of the tested technologies

| Results 1998 | Conventional (n =10) | | | LEISA (n = 7) | | |
|---|---|---|---|---|---|---|
| | $T_{1conv}$ | $T_{2conv}$ | $T_{3conv}$ | $T_{1LEISA}$ | $T_{2LEISA}$ | $T_{3LEISA}$ |
| Maize yield kg/ha | 2,394 (42) | 3,226 (45) | 3,940* (23) | 2,237 (57) | 3,236 (39) | 4,314* (38) |
| Gross returns Ksh/ha | 38,076 (38) | 47,023 (48) | 55,108 (28) | 36,188 (36) | 48,158 (31) | 61,267 (32) |
| Total variable costs Ksh/ha | 15,405 (12) | 18,975 (15) | 22,818 (22) | 13,396 (19) | 19,861 (28) | 25,317 (22) |
| Gross margin Ksh/ha | 22,671 (64) | 28,048 (80) | 32,290 (42) | 22,792 (52) | 28,297 (43) | 35,950 (38) |
| Net Cash income Ksh/ha | 20,849 (48) | 30,895 (47) | 39,386* (23) | 21,849 (53) | 32,361 (39) | 43,138* (38) |
| Return to labour Ksh/ha | 341 (52) | 363 (56) | 270 (30) | 307 (44) | 414 (55) | 296 (49) |
| Partial-N balance kg/ha | -31 | -1 | 13 | -51 | -6 | 19 |
| Partial-P balance kg/ha | 7 | 1 | 4 | -9 | 1 | 5 |

Key: $T_{1conv}$ = 16 t/ha compost; $T_{2conv}$ = $T_{2LEISA}$ = 32 t/ha compost; $T_{3conv}$ = $T_{3LEISA}$ = 32 t/ha compost + 7 t/ha liquid manure; $T_{1LEISA}$ = 16 t/ha 'Boma' manure + 50 kg/ha DAP. * Significant ANOVA P < 0.05. In parenthesis is given the CV %. Formulas used for calculating the economic indicators are presented in Annex 4.

## Shelled grain yield performance

Table 6 shows that in both farming systems, grain yields attained by the new technologies ($T_2$ and $T_3$) were higher than that for normal practices ($T_1$). Top dressing using liquid manure resulted in the highest maize grain yields. The combined application ($T_3$) results in significantly higher maize yields which increased by 33 % on LEISA farms and by 11 % for conventional farming systems, when compared with normal practices.

## Economic performance

Although not statistically significant, the gross margins for maize cultivation were observed to be higher for the new technologies under both LEISA and conventional farm management. Application of liquid manure combined with compost ($T_3$) increased gross margins by 27 % and 15 % in LEISA and conventional farming systems respectively. This was in agreement with farmers' own evaluations.

# Labour

The returns to labour were higher than the opportunity cost for labour, despite the high labour requirements of the new technologies (see Table 7), but decreased for the treatment involving the application of liquid manure($T_3$). Yet, farmers in Machakos regard inputs requiring cash payments as costly. Family labour is not always perceived as "a cost", although it has opportunity cost. Moreover, unemployment rates are high and household members help assure the family's food security through farming. It is therefore possible that some farmers may be willing to adopt the most labour intensive treatment given its higher yield and more positive effect on soil quality. Labour inputs are presented in Table 7. The table shows that total labour demand was mainly derived from family labour sources.

Table 7. Labour demand (days/ha) for the tested technologies

| Description | Conventional | | | LEISA | | |
|---|---|---|---|---|---|---|
| | $T_{1conv}$ | $T_{2conv}$ | $T_{3conv}$ | $T_{1LEISA}$ | $T_{2LEISA}$ | $T_{3LEISA}$ |
| Total | 92 (29%) | 99 (27%) | 162 (34%) | 103 (27%) | 108 (41%) | 100 (57%) |
| % Female labour | 54 | 51 | 65 | 26 | 16 | 30 |
| % Hired labour | 16 | 20 | 12 | 7 | 0 | 0 |

Key: $T_{1LEISA}$ = 16 t/ha compost; $T_{2LEISA}$ = 32 t/ha compost; $T_{3LEISA}$ = 32 t/ha compost + 7 t/ha liquid manure; $T_{1conv}$ = 16 t/ha Boma manure + 57 kg/ha DAP. Averages with CV in parenthesis

The new technologies tended to be accompanied by slightly higher female labour inputs. Female labour and hired labour inputs were also higher in conventional farming systems than in LEISA farming systems. This can be attributed to the high number of female headed households (Table 1) as well as their lack of experience with LEISA technologies. The conventional farmers who were trying out these technologies for the first time found some of these too labour intensive and therefore engaged some hired labour. However, in total, they spent less time than LEISA farmers, because hired labour tend to work faster. In addition, other studies have shown that members of conventional households tend to be more involved in off-farm activities than LEISA households. Part of this off-farm income is then used in hiring labour for farming activities (De Jager *et al.*, 1999).

# Nutrient budgets

Rates of input application and the quality of inputs used for maize cultivation are presented in Annex 4. In both systems, nutrients were supplied in planting holes which is a more effective system than spreading the inputs over the entire field. However, the release and uptake of these nutrients and their impacts on maize performance largely depend on the type and source of nutrients used. Nutrients derived from inorganic fertilisers are "assumed" to be fully available for plant growth in the season of application. On the other hand, availability of N, P, and K from compost is estimated at respectively about 25%, 100% and 80 % in the season of application (Dalzell *et al.* 1979). Muller-Samann and Kotschi (1994), found that Nitrogen availability from manure was only 45 % of the efficiency of inorganic fertilisers while the availability of P and K was similar to inorganic fertilisers[3]. Using these figures, available nutrients supplied for maize cultivation and partial nutrient budgets have been calculated (see Annex 3).

Table 6 shows partial Nitrogen balances were -51 kg/ha for $T_{1LEISA}$, -6 kg/ha for $T_{2LEISA}$ and +19 kg/ha and for $T_{3LEISA}$ (LEISA farms). In conventional farms, these results were -51 kg/ha for $T_{1conv}$, -1 kg/ha for $T_{2conv}$ and +13 kg/ha for $T_{3conv}$. Partial phosphorus balances in LEISA farms were respectively -9 kg/ha, +1 kg/ha and +5 kg/ha for $T_{1LEISA}$, $T_{2LEISA}$ and $T_{3LEISA}$. In conventional farms the results were respectively +7 kg/ha, +1 kg/ha and +4 kg/ha. These results indicate that a combination of compost and liquid manure has a positive effect on partial nitrogen and phosphorus balances. Application rates for compost used in these tests were sufficient to turn negative nitrogen balances into a positive balance, but involved very high quantities of compost. Few farmers would have the capacity to apply these quantities each year on all their fields. Currently, farmers in Machakos apply inputs (compost and manure) to different portions of the farm according to their perceived fertility levels. Cultivated land will thus be fertilised once every 3-5 seasons.

# Farmers' evaluation

The results for individual farmers are presented in Table 8. It is based on farmers distributing 10 points among the three treatments studied. This scoring was done according to the perceived importance of a given evaluation criterion for the three treatments. This table shows that, overall, a combination of compost and liquid manure technologies ($T_3$) is rated highest in both LEISA and conventional farming systems, followed by the compost application rate of 32 t/ha ($T_2$) and normal farmers' practices ($T_1$).

Both groups of farmers regarded the combination of compost and liquid manure as scoring best on improved soil structure, soil fertility, crop growth and vigour, leaf colour

[3] These percentages are influenced by climatic soil characteristics

Table 8. Evaluation by Individual farmers of technologies tested*

| | Conventional farms (n = 10) | | | LEISA farms (n = 7) | | |
|---|---|---|---|---|---|---|
| **Criteria/ indicator** | $T_{1conv}$ | $T_{2conv}$ | $T_{3conv}$ | $T_{1LEISA}$ | $T_{2LEISA}$ | $T_{3LEISA}$ |
| Soil structure | 2.1 | 3.1** | 4.9* | 2.3 | 3.1* | 4.6* |
| Soil fertility | 1.9 | 3.1* | 5** | 2 | 3.7** | 4.3* |
| Labour x quantity | 2.6 | 2.7** | 4.7** | 2 | 3.1** | 4.9** |
| Quantity of compost or manure needed | 2 | 3.3** | 4.6** | 1.9 | 3.4** | 4.7** |
| Quantity of seeds | 2.9 | 3.6 | 3.6 | 3.3 | 3.7 | 3 |
| Incidence of weeds | 2.2 | 2.8** | 4.7* | 2 | 3.1** | 4.9** |
| Crop vigour / fast growth* | 4.2 | 2.4* | 3.6* | 2 | 3.4* | 4.6* |
| Leaf colour | 3.6 | 2.3* | 4.1** | 2 | 3 | 5** |
| Pest or disease attack | 3.1 | 3.1 | 3.9 | 4.4** | 2.9 | 2.7 |
| Money saving | 2.1 | 3.1* | 4.7** | 2.9 | 3 | 4.1** |
| Yield | 2.6 | 2.6 | 4.8** | 2 | 3.4** | 4.6** |

* Figures present the distribution of 10 points over three treatments scores do not always add up to 10

Kruskal-Wallis analysis of variance by ranks (* P 0.05 ** P 0.01)

intensity, maize yields and saved cash inputs. However, both groups of farmers also noted that this technology was very demanding in the labour and inputs required for making compost and also resulted in more problems with weeds.

Some of the constraints faced by farmers when using the new technologies were problems with pests (maize stalk borer) and diseases (head smut). The fast spread of head smut was attributed to the humid and sometimes windy conditions experienced during the trials. The quality of maize seeds was also judged as poor which, in combination with the proposed depth of planting, resulted in poor germination in some fields. This was further aggravated by the relatively late installation of the trail. The results of a discussion session initiated with farmers on how to offset constraints experienced during trials (Table 8 ) are presented in Table 9.

During the discussions on the design of the experiment, farmers suggested dry planting of seed instead of at the onset of rains. Their reasoning is that this will improve the chance of getting a good harvest in case the rains falter in the course of the season. Early planting is also perceived as being important for taking advantage of the nitrogen flush so that seeds and young seedlings can compete effectively with weeds.

Table 9. Farmers' constraints during the trials and possible solutions

| Constraint | Possible solutions |
|---|---|
| Poor quality seed | • Proper selection of indigenous seeds<br>• Air drying of seeds<br>• Treatment with wood ash, *Croton sp.* leaves, etc. |
| Poor seed germination | • Use of good quality seeds/ selected seeds for planting<br>• Planting at proper depth (2-3 inches)<br>• Planting when environmental conditions are favourable;<br>• dry planting |
| Head smut | • Avoid passing infected plant parts through composting process<br>• Uprooting and burning of infected plants |
| Maize stalk borer | • Use of cultural practices;<br>• composting of crop residues<br>• sprinkle of ash<br>• Use of botanicals such as tobacco and marigold |

# 4 Conclusion

This study has shown that using a PTD approach, farmers and researchers can come to agreement on technologies to be tested, various treatments and research design. Matching the results of farmers' evaluation with the calculations by researchers is useful for assessing the potential of soil fertility management technologies.

The analysis of data collected by researchers on the performance of the various treatments correlates well with farmers' evaluation. Both LEISA and conventional farmers consider that the treatment that combines compost with liquid manure produces the best results. This treatment also resulted in a significantly higher net cash income than either compost application alone or a combined application of manure and DAP. Positive features identified by farmers are an improvement of soil structure, soil fertility, crop growth and vigour, leaf colour intensity and maize yields. It also saves on cash inputs as it replaces fertilisers in the case of conventional farmers. Yet, the new technologies are considered to demand a lot of labour and require substantial amounts of organic material for producing compost.

Agro-economic evaluation of the technologies under study has also shown that a combined application of compost and liquid manure results in significantly higher grain yields and net cash income when compared with normal farmer practice. Although not statistically significant, the same trend was observed for gross margins. Doubling the current rate of compost application also resulted in higher yields, gross margins, net cash income and return to labour when compared with normal farming practices for both groups of farmers.

Assessment of labour inputs needed for a technology is important for evaluating its performance. The results of this study show that total labour required for the technologies tested was higher than that of normal farmer practice. Although the return to labour was higher than the opportunity cost in the research site for all technologies studied, the marginal return started to decline at higher levels of nutrient application through top dressing with liquid manure.

The calculation of a partial nutrient budget showed that current management practices for maize cultivation in Machakos for both LEISA and conventional farmers resulted in

net negative nitrogen and phosphorus balances. This is still the case for partial nitrogen balances when the compost application rate is doubled, though the phosphorus balance becomes positive. Only the combined use of compost and liquid manure has a positive impact on both nitrogen and phosphorus balances. A further insight into the performance of these technologies is expected through analysis of residual effects of the treatments in the second year of the trials.

# References


**Altieri, M.N., Beniest, J., Sanchez, P.A., Swift, M.J. and A. van Houten (Eds.).** 1997. *Approaches to replenishing soil fertility in Africa: NGO perspectives.* Summary of workshop held in Nairobi Kenya. ICRAF, Nairobi.

**Ashby, A.J.** 1991. *Evaluating Technology with farmers: A hand book.* IPRA/projects, CIAT and The Kellogg Foundation.

**Brokensha, D., Warren, D. M. and O. Warner.** 1980. *Indigenous knowledge systems and development.* UN Press of America, Lanham, USA.

**Chambers, R. (Ed.)** 1991. *Participatory Rural Appraisal.* Proceedings of the February 1991 Bangalore PRA trainers' workshop. RRA notes No. 13. IIED, London.

**Conway, G. R.** 1987. *The properties of Agro-ecosystems.* Agric. Syst., 24: 95-117.

**Dalzell, H.W., Gray, K.R. and A.J. Biddlestone.** 1979. *Composting in tropical agriculture.* The International Institute of Biological Husbandry. Review Papers, Series No. 2, Ipswich, England.

**Defoer, T., De Groote, H., Hilhorst, T., Kanté, S. and Budelman, A.** 1998. Participatory action research and quantitative analysis for nutrient management in southern Mali: a fruitful marriage? *Agriculture, Ecosystems, and Environment,* Vol. 71 Nos. 1, 2, 3. pp 215-228.

**DAO.** 1996. *District annual report, Machakos District.* Draft report.

**De Jager, A., Onduru, D.D., Wijk, M. S., Vlaming, J. and G.N. Gachini.** 1999. Assessing potentials of Low External Input farm technologies with the nutrient monitoring approach: A case study in Kenya. *Agriculture, Ecosystems, and Environment,* (forthcoming)

**Diop, J-M., Onduru, D.D., Werf, van der, E. and J. Kariuki.** 1997. *On-farm Agro-economic study of organic and conventional techniques in medium and high potential areas of Kenya.* KIOF/ETC-Netherlands, Nairobi.

**Deugd, M., Röling, N., and E.M.A. Smaling.** 1998. A new praxeology for Integrated Nutrient Management: Facilitating innovation with and by farmers. *Agriculture, Ecosystems, and Environment,* Vol. 71 (1998) Nos. 1,2,3 pp 269-283.

**Hamilton, P.** 1997. *Goodbye to hunger: The adoption and diffusion and impacts of conservation farming practices in rural Kenya.* ABLH, Nairobi.

**Jaetzold, R. and H. Schmidt.** 1982. *Farm management hand book of Kenya.* Volume II. Natural conditions and farm management information. Ministry of Agriculture, Kenya.

**Kariuki, J., Onduru, D. D. and M. Muchoki.** 1994. *Organic farming adoption survey.* KIOF, Nairobi.

**Kassam, A. H., Velthuizen, H. T., Fischer, G. W. and M.M. Shah.** 1991. *Agro-ecological land resources assessment for agricultural development planning.* A case study of Kenya. Resources data base and land productivity. Technical Annex 1. Land resources. Land and Water Development Division, FAO and IIASA, pp 9-31. Rome.

**McCown, R. L. and R.K. Jones.** 1990. *Agriculture of semi-arid Eastern Kenya; Problems and possibilities.* In: Probert, M. E. (Ed.). A search for strategies for sustainable dryland cropping in semi-arid Eastern Kenya. Proceedings of a symposium held in Nairobi, Kenya, 10th-11th December 1990. ACIAR proceedings No. 41.

**Müller-Sämann, K.M, and J. Kotschi.** 1994. *Sustaining growth-soil fertility management in tropical small-holdings.* CTA-GTZ, Margraf Verlag, Weikereheim, Germany.

**Onduru, D. D., Nandwa, S.M and G.N. Gachini.** 1998. *Experiences in participatory diagnosis of soil nutrient management in Kenya.* Managing Africa's Soils No. 3. IIED, UK.

**Reijntjes, C. B., Haverkort, B. and A. Waters-Bayer.** 1992. *Farming for the future: An introduction to Low External Input and Sustainable Agriculture.* Macmillan, ILEA, Leusden.

**Steiner, K. G.** 1987. *On-farm experimentation handbook for rural development projects: Guidelines for the development of ecological and socio-economic sound extension messages for small farmers.* GTZ, Eschborn, Germany.

**Swiss Directorate for Development Co-operation (SDC).** 1993. *Participatory Rural Appraisal* (PRA). SDC.

**Tiffen, M., Mortimore, M. and F. Gichuki.** 1994. *More people less erosion. Environmental recovery in Kenya.* ACTS, Nairobi, Kenya and ODI, London.

**Vlaming, J., Gitari, J. N. and M.S. van Wijk.** 1997. *Farmers and researchers on their way to Integrated Nutrient Management.* LEISA: ILEA Newsletter for Low External Input and Sustainable Agriculture. Vol. 13, No.3 pp 6-8.

**Werner, J.** 1993. *Participatory development of agricultural innovations: procedures and methods of on-farm research.* Technical Co-operation, Federal Republic of Germany, Eschborn, Germany.

## Annex 1. Farmers and researchers suggested treatments on maize

### Treatments suggested by conventional farmers

- I/2 Kg tinful of boma manure + inorganic fertilisers at normal farmers rate + normal tillage (plot 1)
- Plant with the usual inorganic fertiliser at normal farmers practice + normal tillage (second option plot 1)
- 1 Kg tinful of compost per planting hole + normal tillage (plot 2)
- 1 kg tinful of boma manure + inorganic fertilisers (at normal practice) + normal tillage (second option plot 2)
- 1 Kg tinful of compost per planting hole + liquid manure (1 cupful) + normal tillage (plot 3).

### Treatments suggested by LEISA farmers

- 1/2 Kg tinful of compost per planting hole + normal tillage (plot 1)
- 1/4 Kg tinful of compost per planting hole + normal tillage (second option on plot 1)
- 1 kg tinful of compost per planting hole + normal tillage (plot 2)
- 1 kg tinful of compost per planting hole + normal tillage + 1 cupful of liquid manure per planting hole (plot 3)
- Individual farmers' own rate of compost application per planting hole + top dressing with "a quarter litre of liquid manure" e.g. 1 cupful when crops are at knee height.

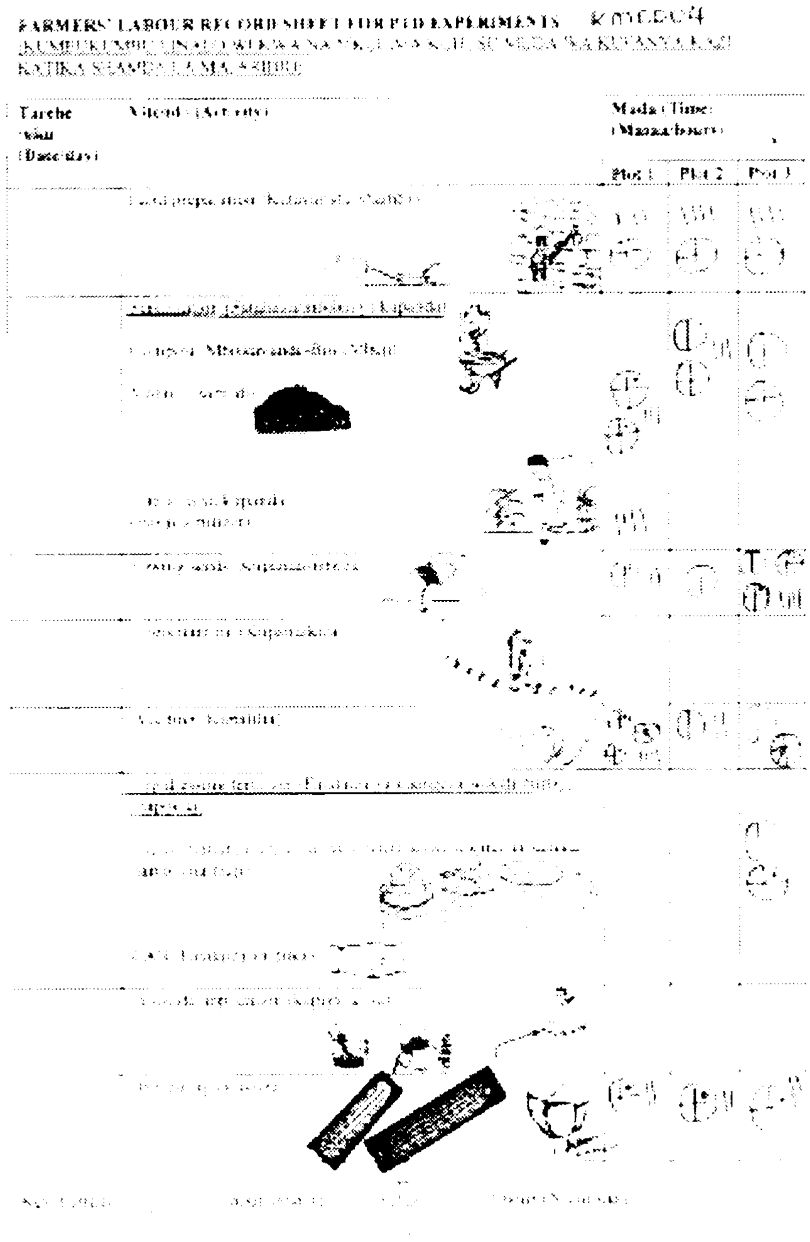
### Treatments suggested by researchers for conventional farmers

- 1/2 Kg tinful of manure + inorganic fertilisers + normal tillage (plot 1)
- 1/2 Kg tinful of compost + normal tillage (second suggestion for plot 1)
- 1 Kg tinful of compost + normal tillage (plot 2)
- 1 Kg tinful of compost + normal tillage + liquid manure (1 cupful) (plot 3)

### Treatments suggested by researchers for LEISA farmers

- 1/4 Kg tinful of compost per planting hole + normal tillage (plot 1)
- 1/2 Kg tinful of compost per planting hole + normal tillage (second option to plot 1)
- 1 kg tinful of compost per planting hole + normal tillage (plot 2)
- 1 kg tinful of compost per planting hole + normal tillage + liquid manure (1 cupful) + normal tillage.

# Annex 2. Example of labour record sheet for farmers



## Annex 3a. Quality of inputs used in Machakos District, Kenya

| | DAP | | | Compost | | | | Boma manure | | | | Liquid manure | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nutrients | N % | P % | K% | N % | P % | K% | Dry matter fraction | N % | P % | K% | Dry matter fraction | N % | P % | K% |
| LEISA | | | | 0.37 | 0.08 | 0.46 | 0.52 | | | | | 0.69 | 0.14 | 0.53 |
| Conventional | 20.81 | 17.47 | 0.09 | | | | | 0.39 | 0.10 | 0.63 | 0.55 | 0.35 | 0.06 | 0.36 |

## Annex 3b. Nutrient inputs (kg/ha) applied for maize cultivation in Machakos

| INPUTS | LEISA | | | | | | | | | Conventional | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $T_1$ | | | $T_2$ | | | $T_3$ | | | $T_1$ | | | $T_2$ | | | $T_3$ | | |
| | N | P | K | N | P | K | N | P | K | N | P | K | N | P | K | N | P | K |
| Compost | 30.78 | 6.66 | 38.27 | 61.56 | 13.32 | 76.54 | 61.56 | 13.32 | 76.54 | 0 | 0 | 0 | 61.56 | 13.32 | 76.54 | 61.56 | 13.32 | 76.54 |
| Boma manure | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 34.32 | 8.8 | 55.44 | 0 | 0 | 0 | 0 | 0 | 0 |
| DAP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11.86 | 9.96 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0 |
| Liquid manure | 0 | 0 | 0 | 0 | 0 | 0 | 48.30 | 9.8 | 37.10 | 0 | 0 | 0 | 0 | 0 | 0 | 48.30 | 9.8 | 37.10 |
| **Total** | **30.78** | **6.66** | **38.27** | **61.56** | **13.32** | **76.54** | **109.86** | **23.12** | **113.64** | **46.18** | **18.76** | **55.49** | **61.56** | **13.32** | **76.54** | **109.86** | **23.12** | **113.64** |

## Annex 3c. Available nutrients (kg/ha) supplied for maize cultivation in Machakos, Kenya

| INPUTS | LEISA | | | | | | | | | Conventional | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $T_1$ | | | $T_2$ | | | $T_3$ | | | $T_1$ | | | $T_2$ | | | $T_3$ | | |
| | N | P | K | N | P | K | N | P | K | N | P | K | N | P | K | N | P | K |
| Compost | 7.70 | 6.66 | 30.62 | 15.39 | 13.32 | 61.23 | 15.39 | 13.32 | 61.23 | 0 | 0 | 0 | 15.39 | 13.32 | 61.23 | 15.39 | 13.32 | 61.23 |
| Boma manure | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15.44 | 8.8 | 55.44 | 0 | 0 | 0 | 0 | 0 | 0 |
| DAP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11.86 | 9.96 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0 |
| Liquid manure | 0 | 0 | 0 | 0 | 0 | 0 | 48.30 | 9.8 | 37.10 | 0 | 0 | 0 | 0 | 0 | 0 | 48.30 | 9.8 | 37.10 |
| **Total** | **7.70** | **6.66** | **30.62** | **15.39** | **13.32** | **61.23** | **63.69** | **23.12** | **98.33** | **27.3** | **18.76** | **55.49** | **15.39** | **13.32** | **61.23** | **63.69** | **23.12** | **98.33** |

## Annex 4: Economic indicators

| | |
|---|---|
| Cash Income (CI) | Total output valued at market prices of output actually sold. |
| Non-Cash Income (NCI) | Total output valued at market prices of output actually home consumed. |
| Gross Income (GI) | Total output valued at market prices (including both output actually sold and home consumed.<br>Gross income: GI = CI + NCI. |
| Cash Costs (CC) | Cash expenditures (external input expenses). |
| Non-Cash Costs (NCC) | Valued internal inputs (e.g. compost, family labour, etc.). |
| Total Variable Costs (TVC) | TVC is equivalent to Cash Costs plus Non-Cash Costs:<br>TVC = CC + NCC |
| Gross Margin (GM) | GM is equivalent to Gross Income minus Total Variable Costs:<br>GM = GI - TVC. |
| Net Cash Income (NCI) | NCI is equivalent to Cash Income minus Cash Costs:<br>NCI = CI - CC. |
| Family Labour Days (FLD) | Is equivalent to the number of hours used by the family for a certain technology divided by 5 |
| Family Labour Costs (FLC) | Is equivalent to the number of family labour days valued at pay rate of labourers for a certain technology (opportunity cost). |
| Total Labour Costs (LC) | Is equivalent to Family Labour Costs (FLC) + Hired labour cost (HLC): TLC = FLC + HLC |
| Total labour days (TLD) | Is equivalent to the number of family labour days + Hired labour days. |
| Return to Labour | = GM + TLC / TLD<br>= {(GI - TVC) + TLC}/ TLD<br>= {(GI - CC - NCC) + TLC}/ TLD |

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**Thea Hilhorst**
**IIED-Drylands Programme**
**4 Hanover Street**
**EH2 2EN Edinburgh**
**United Kingdom**
**Tel: +44 131 624 7042**
**Fax: +44 131 624 7050**
**E-mail: thea.hilhorst@iied.org**

ISSN 1560-3520